Age-related variations in the horizontal and vertical diameters of the pedicles of the lumbar spine

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ABSTRACT

The horizontal and vertical diameters of the pedicles of the lumbar vertebrae were measured from plain anteroposterior radiographs of the lumbar spines of male and female subjects aged from 10 to 65 y. The results showed that there were significant differences between the pedicle diameters of males and females. Horizontal diameters ranged from 7.4 to 13.6 mm in females and from 7.5 to 14.2 mm in males. Female vertical diameters ranged from 14.2 to 18.2 mm whilst male vertical diameters ranged from 14.8 to 20.7 mm. Generally, there was a cephalocaudal increase of diameters in both sexes. Significant age-related variations of pedicle diameters were noted at all segmental levels. Within the adolescent group (10–19.9 y), the diameters of the 10–14.9 y group and 15–19.9 y group differed significantly ($P < 0.001$). When the pedicle diameters of the individual age groups were compared, the pedicles of the 10–19.9, 20–29.9, 30–34.9, 40–49.9, and 50+ y groups were found to be significantly different from each other. The evidence suggests that pedicle diameters undergo continuous change throughout the age range studied. The changes are characterised by increase of diameters in some age groups and decrease in others, but there was an overall increase of both vertical and horizontal diameters as the age groups were followed from the youngest to the oldest. The pattern of variation with age differed for horizontal and vertical diameters. After the 5th decade, female horizontal and vertical diameters showed a tendency to increase while male diameters decreased.

Key words: Lumbar spine; vertebral neural arch pedicles; age changes.

INTRODUCTION

The last two decades have seen an increasing use of transpedicular screw instrumentation techniques as a means of spinal fixation (Stefee et al. 1986; Lorenz et al. 1993). Zindrick (1991) described the screw fixation procedure as the method of choice for stabilisation of the lumbosacral spine. Many types of pedicle screw systems have been developed. Basically, they all entail the insertion of screws through the pedicle (from the posterior aspect) into the vertebral body. The screws enable various devices (plates, rods or wires) to be applied to the spine for the purpose of immobilisation or fixation. The success of the technique depends upon the ability of the screw to obtain and maintain purchase within the vertebral body (Zindrick et al. 1986). This is determined, among other factors, by the accuracy of choice of screw, size of the pedicle and the quality of the bone of the pedicle. Loosening of the screw, and penetration or fracture of the cortical bone shell of the pedicle are common causes of device failure that may be associated with serious complications. Penetration of the cortex or fracture of the pedicle may result from the use of relatively oversized screws. Some of the complications that have been reported include dural tears, leakage of cerebrospinal fluid and injuries to the nerve roots with neurological deficits (Krag et al. 1985; Zindrick et al. 1986; Esses & Sachs, 1992; Weinstein et al. 1992). Most surgeons prefer to use as large a screw as possible for any given pedicle because, as Zindrick et al. (1986) observed, larger-diameter screws were stronger and gave better results. The choice of screw for the procedure is, nevertheless, determined by the minimum (horizontal) diameter of the pedicle (Krag et al. 1986; Zindrick et al. 1987; Weinstein et al. 1992).

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Morphometric data on the diameters of the pedicles are therefore useful in preoperative planning and in the designing of pedicle screws. Norms of the vertical and horizontal diameters of thoracic and lumbar pedicles have been published (Saillant, 1976; Krag et al. 1986; Roy-Camille et al. 1986; Zindrick et al. 1986, 1987; Berry et al. 1987; Scoles et al. 1988; Weinstein et al. 1992). The reports were based on studies of samples of adult material ranging in age from 20 to 80 y. There appears to be no information on the pedicle diameters of younger subjects although, as Bauer & Errico (1991) pointed out, a greater proportion of the patients needing lumbar spinal fixation belong to the younger segment of the population.

Reporting on a follow-up of 19 postoperative cases, McLain et al. (1993) cautioned that there was 'an alarming rate of early failure of screw fixation' in cases of thoracolumbar fracture managed by pedicle screw instrumentation. The duration of follow-up of the patients ranged from 5 to 28 months. Possible weaknesses in the screws and techniques of application were suggested as probable causes of device failure. It is noteworthy, however, that 16 of the 19 patients surveyed (84%) were younger than 35 y old. Seven out of the 16 were aged 20 y or younger. This age group is normally characterised by a high velocity of growth—the growth spurt that is experienced at adolescence. Would the diameters of the pedicles of these growing individuals remain unchanged? This information would be especially useful in the follow-up of growing pedicles that have indwelling screws.

With the exception of the report of Scoles et al. (1988), most published norms of pedicle diameters appear to have been based on measurements of mixed populations of male and female subjects. The samples studied by Berry et al. (1987) and Scoles et al. (1988) were apparently obtained from the same source (Scoles et al. 1988). Berry et al. (1987) examined 30 specimens ranging in age from 50 to 80 y. They did not separate male and female specimens. The sample studied by Scoles et al. (1988) consisted of 25 male and 25 female spines ranging in age from 20 to 40 y. Scoles et al. (1988) not only reported smaller pedicle diameters than Berry et al. (1987), but they also noted that there were slight differences between male and female pedicle diameters. The questions that arise are: (1) Are there significant differences between the diameters of the pedicles of young and old individuals? (2) Are there significant differences between the pedicle diameters of males and females of identical ages?

The present study was undertaken in an attempt to find answers to these questions.

MATERIALS AND METHODS

Many techniques, including osteometry (Berry et al. 1987; Scoles et al. 1988), measurements from plain radiographs (Baddely, 1976; Zindrick et al. 1987) and computerised tomograms (Krag et al. 1986; Zindrick et al. 1987; Weinstein et al. 1992) have been used to study vertebral pedicles. Outlines of the pedicles are well demarcated on plain anteroposterior radiographs and accurate measurements may be made directly from the films (Baddely, 1976; Zindrick et al. 1986). Comparative studies reported by Zindrick et al. (1986, 1987), Weinstein et al. (1992), Errico & Palmer (1993) established that measurements obtained directly from plain films correlated well with values measured from computerised tomograms and from anatomical specimens.

Plain anteroposterior radiographs of the lumbar spines of 540 subjects (270 males, 270 females) with ages ranging from 10 to 65 y, were studied. Radiographs were selected from the records of patients who had attended the Accident and Emergency unit of the King Khalid University Hospital with suspected recent accidental injury to the spine and in whom no bony injury could be found. No subjects were routinely exposed to x-rays. A standardised technique was used in taking all the radiographs. The same radiographic equipment was used in all cases. Patients were x-rayed in the recumbent position. The x-ray beam was centred on the 3rd lumbar vertebra and directed at 90° to the film. An anode-film distance of 100 cm was maintained. The magnification resulting from the use of this technique was negligible. All films were screened for readability and certified to be free from spinal pathology by a diagnostic radiologist.

Selection of subjects

Care was taken to exclude individuals with a history of back pain over the past 12 month period or patients receiving treatment for back pain. Other exclusion criteria that were used to select radiographs were: (1) history of surgery for disorders related to the vertebral column; (2) history of growth disorders; (3) history of systemic bone disease or chronic renal disease; (4) history of malabsorption; (5) evidence of scoliosis, kyphosis or other spinal pathology.

Male and female subjects were grouped separately into 5 age groups. Each age group spanned 10 y. Subjects aged 50 y and over were grouped together as 50+ y. The age and sex distribution of the sample are shown in Table 1.

Table 1. *Distribution of sample according to age groups and sex*

Age group (y)	Females (n)	Males (n)
10–19.9	60	60
20–29.9	60	60
30–39.9	60	60
40–49.9	60	60
50+	30	30

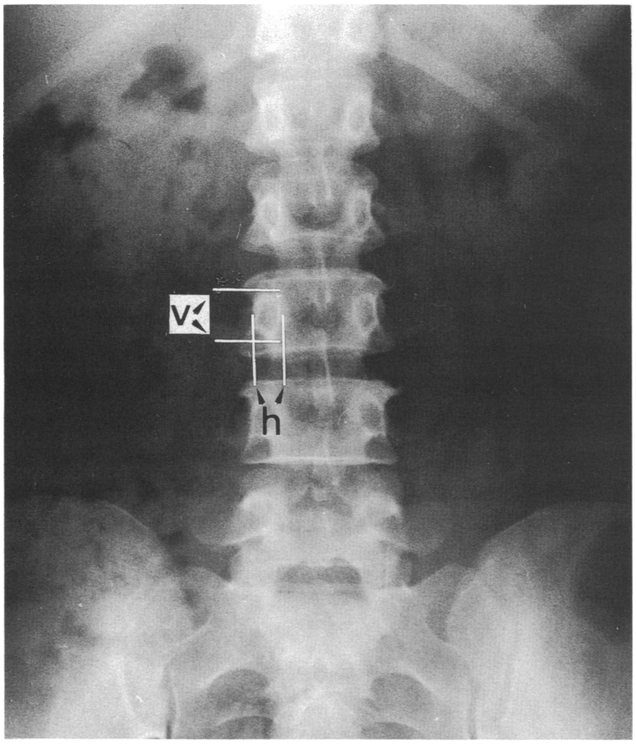

Fig. Anteroposterior radiograph of the lumbar spine illustrating the landmarks used for measuring the diameters of the pedicle. v, vertical diameter; h, horizontal diameter.

Measurements

Pedicle diameters were measured in 2 mutually perpendicular planes, v and h (see Fig.). On the plain radiograph, the outline of the pedicle is somewhat oval. The vertical diameter (v) was taken as the maximum dimension of the pedicle in the sagittal plane. At the lower lumbar levels, the plane of the vertical diameter was oblique, with the upper end nearer the midline than the lower. The horizontal diameter, h, was the maximum diameter in a plane at right angles to the vertical diameter. Pencil marks were first placed on the limits of the pedicle. Distances were then measured by means of a digitising tablet connected to a microcomputer. All measurements were made by the author. Each radiograph was measured twice, at separate sittings, the second measurement serving as a check on the first. Right and left pedicles were measured at each level. No differences were noted between the diameters of corresponding right and left pedicles. The marks were completely erased from the films between measurements to avoid bias during the second reading. Differences between initial and repeat readings ranged from 0 to 0.11 mm with a median of 0.04 mm.

Statistical analyses

The mean (horizontal and vertical) diameters, standard errors of the means (S.E.M.) and standard deviations (S.D.) of the diameters of the pedicles of all the lumbar vertebrae (L1 to L5) were calculated (separately for males and females) using the StatPac Gold statistical analysis package. Differences between the mean diameters of the pedicles of males and females belonging to the various age groups were tested by means of a 2-way analysis of variance (2 factor factorial ANOVA) in a completely randomised design, with vertebral level as a covariate. Multiple 2-tailed t tests were used in combination with ANOVA to test the differences between individual mean diameters. 95% confidence limits of the mean diameters [mean ± 1.96(S.E.M.)] were calculated for all age groups at all levels.

RESULTS

General observations

The mean horizontal and vertical diameters of the pedicles of the 1st–5th lumbar (L1–L5) vertebrae of males and females are tabulated in Tables 2–6. The tables also show the 95% confidence limits of the pedicle diameters calculated for the various age groups at all 5 lumbar levels and the results of the t tests of the differences between male and female mean diameters. There were significant differences ($P < 0.001$) between the mean diameters of the pedicles of males and females at all lumbar levels in most age groups (Tables 2–6). As a rule, in the 10–19.9 y age group, the mean diameters of female pedicles were greater than the mean diameters of male pedicles. A reversal was noted from age group 20–29.9 y upwards, with male diameters exceeding those of females. Differences between the pedicle diameters of males and females in the 6th decade were mostly not statistically significant. At all 5 lumbar levels, differences were noted between the mean diameters of the pedicles of the various age groups. Differences between contiguous age groups were small in some cases. However, ANOVA showed that at each of the 5 lumbar levels, the variations of

Table 2. *Diameters of the pedicles of L1 vertebra of females and males*

Age group (y)	Diameter	Females: Mean diam. (mm)	Females: S.E.M.	Females: 95% confidence limits (mm)	Males: Mean diam. (mm)	Males: S.E.M.	Males: 95% confidence limits (mm)	P*
10–19.9	Horizontal	9.8	0.3	9.3–10.3	7.5	0.2	7.1–7.9	< 0.001
	Vertical	15.5	0.2	15.1–15.9	15.4	0.3	14.8–16.0	ns
20–29.9	Horizontal	7.4	0.2	7.1–7.7	9.3	0.2	9.0–9.6	< 0.001
	Vertical	15.1	0.2	14.6–15.5	18.2	0.1	17.9–18.4	< 0.001
30–38.9	Horizontal	8.3	0.2	8.0–8.7	9.6	0.2	9.1–9.9	< 0.001
	Vertical	16.2	0.2	15.8–16.6	17.2	0.2	16.9–17.5	< 0.001
40–49.9	Horizontal	8.7	0.2	8.4–8.9	10.3	0.3	9.9–10.6	< 0.001
	Vertical	16.3	0.2	15.9–16.7	19.4	0.3	18.9–19.9	< 0.001
50+	Horizontal	8.5	0.2	8.2–8.8	9.5	0.2	9.0–10.0	< 0.001
	Vertical	17.2	0.2	16.8–17.6	17.6	0.2	17.1–18.0	ns

**P*, difference between mean diameters of females and males; ns, not significant.

Table 3. *Diameters of the pedicles of L2 vertebra of females and males*

Age group (y)	Diameter	Females: Mean diam. (mm)	Females: S.E.M.	Females: 95% confidence limits (mm)	Males: Mean diam. (mm)	Males: S.E.M.	Males: 95% confidence limits (mm)	P*
10–19.9	Horizontal	10.5	0.3	10.0–11.1	8.3	0.2	7.8–8.7	< 0.001
	Vertical	14.6	0.3	14.1–15.1	14.9	0.3	14.2–15.6	ns
20–29.9	Horizontal	8.1	0.2	7.8–8.4	9.9	0.2	9.4–10.4	< 0.001
	Vertical	15.3	0.2	14.9–15.7	17.8	0.1	17.9–18.1	< 0.001
30–39.9	Horizontal	8.6	0.2	8.3–8.8	10.3	0.3	9.8–10.7	< 0.001
	Vertical	15.7	0.2	15.3–16.1	17.5	0.2	17.1–17.8	< 0.001
40–49.9	Horizontal	9.0	0.2	8.7–9.4	10.7	0.2	10.3–11.2	< 0.001
	Vertical	15.3	0.2	15.0–15.7	18.9	0.3	18.4–19.4	< 0.001
50+	Horizontal	9.1	0.3	8.5–9.7	9.9	0.4	9.2–10.6	ns
	Vertical	16.8	0.2	16.5–17.1	17.6	0.2	17.3–17.5	ns

**P*, difference between mean diameters of females and males; ns, not significant.

Table 4. *Diameters of the pedicles of L3 vertebra of females and males*

Age group (y)	Diameter	Females: Mean diam. (mm)	Females: S.E.M.	Females: 95% confidence limits (mm)	Males: Mean diam. (mm)	Males: S.E.M.	Males: 95% confidence limits (mm)	P*
10–19.9	Horizontal	11.9	0.3	11.3–12.4	9.7	0.2	9.3–10.2	< 0.001
	Vertical	15.1	0.2	14.6–15.5	14.8	0.3	14.1–15.4	ns
20–29.9	Horizontal	9.0	0.2	8.6–9.4	11.6	0.2	11.2–12.0	< 0.001
	Vertical	15.9	0.2	15.5–16.2	17.7	0.1	17.5–17.9	< 0.001
30–39.9	Horizontal	10.5	0.2	10.1–10.9	11.8	0.3	11.3–12.4	< 0.001
	Vertical	16.3	0.2	15.9–16.6	17.0	0.1	16.8–17.2	< 0.001
40–49.9	Horizontal	10.5	0.2	10.1–10.8	12.1	0.3	11.6–12.6	< 0.001
	Vertical	15.9	0.2	15.5–16.2	19.3	0.3	18.7–19.9	< 0.001
50+	Horizontal	11.3	0.3	10.7–12.0	12.1	0.3	11.4–12.8	ns
	Vertical	17.1	0.2	16.7–17.5	16.8	0.2	16.3–17.3	ns

**P*, difference between mean diameters of females and males; ns, not significant.

Table 5. *Diameters of the pedicles of L4 vertebra of females and males*

		Females			Males			
Age group (y)	Diameter	Mean diam. (mm)	S.E.M.	95% confidence limits (mm)	Mean diam. (mm)	S.E.M.	95% confidence limits (mm)	P*
10–19.9	Horizontal	11.7	0.3	11.1–12.3	11.0	0.3	10.4–11.6	< 0.10
	Vertical	15.2	0.2	14.8–15.7	15.5	0.4	14.2–16.3	ns
20–29.9	Horizontal	11.4	0.2	10.9–11.8	12.7	0.2	12.2–13.1	< 0.001
	Vertical	16.3	0.1	16.1–16.5	18.7	0.1	18.5–19.0	< 0.001
30–39.9	Horizontal	11.8	0.1	11.5–12.1	12.8	0.2	12.3–13.3	< 0.001
	Vertical	17.3	0.1	17.0–17.5	17.7	0.2	17.4–18.0	< 0.05
40–49.9	Horizontal	11.1	0.2	10.6–11.5	13.0	0.2	12.7–13.4	< 0.001
	Vertical	16.1	0.1	15.9–16.3	19.9	0.3	19.4–20.5	< 0.001
50+	Horizontal	11.9	0.2	11.5–12.3	13.3	0.2	12.9–13.7	< 0.001
	Vertical	17.6	0.2	17.3–17.9	18.1	0.2	17.8–18.5	< 0.05

*P, difference between mean diameters of females and males; ns, not significant.

Table 6. *Diameters of the pedicles of L5 vertebra of females and males*

		Females			Males			
Age group (y)	Diameter	Mean diam. (mm)	S.E.M.	95% confidence limits (mm)	Mean diam. (mm)	S.E.M.	95% confidence limits (mm)	P*
10–19.9	Horizontal	12.0	0.3	11.4–12.6	11.5	0.3	10.9–12.0	ns
	Vertical	17.3	0.2	16.8–17.8	16.7	0.4	15.9–17.4	ns
20–29.9	Horizontal	11.9	0.2	11.5–12.2	13.6	0.2	13.3–14.0	< 0.001
	Vertical	17.6	0.2	17.3–18.0	19.3	0.1	19.0–19.6	< 0.001
30–39.9	Horizontal	12.4	0.1	12.1–12.7	13.7	0.2	13.2–14.2	< 0.001
	Vertical	18.2	0.2	17.9–18.5	18.8	0.2	18.4–19.2	< 0.02
40–49.9	Horizontal	12.5	0.2	12.0–12.9	14.2	0.3	18.8–14.6	< 0.001
	Vertical	17.5	0.1	17.2–17.7	20.7	0.4	20.0–21.4	< 0.001
50+	Horizontal	13.6	0.2	13.2–14.0	13.3	0.2	12.8–13.8	ns
	Vertical	17.8	0.2	17.3–18.3	18.6	0.3	18.1–19.1	< 0.02

*P, difference between mean diameters of females and males; ns, not significant.

the mean (horizontal and vertical) diameters from age group 10–19.9 y to age group 50+ y were highly significant in both females and males. The 10–19.9 y age group includes the period of the adolescent growth spurt during which there is accelerated growth activity resulting in marked bodily changes. The timing of the onset and the peak of the increased growth velocity differ in males and females. Multiple 2-tailed t tests, done separately for the male and female populations, showed that, in general, the differences between the mean pedicle diameters of age groups 10–14.9 and 15–19.9 y were highly significant ($P < 0.001$). The diameters of the 15–19.9 y age group were greater than the diameters of the 10–14.9 y age group and the diameters of females belonging to the 20–29.9 y age group. Furthermore, the mean diameters of individuals in early life (namely 10–19.9 y) differed significantly from the diameters of subjects in middle life (30–39.9 and 44–49.9 y). Differences between the mean pedicle diameters of individuals in the 5th and 6th decades were also found to be significant. The details of the variations of the mean diameters from the youngest age group to the oldest were different for horizontal and vertical diameters. These differences are described separately below.

Intersegmental differences

Horizontal diameters. There was a cephalocaudal gradient of increase (from L1 to L5) of the horizontal diameters of male and female pedicles in all age groups except males of the 5th decade. In the latter population the mean horizontal diameters of the L3 pedicles were somewhat greater than the diameters of the corresponding L4 pedicles, although the differences were not statistically significant. The smallest horizontal diameter of the female pedicles was 7.4 mm at L1 in the 20–29.0 y age group (Table 2). The maximum horizontal diameter was 13.6 mm at L5 in the 50+ y age group (Table 6). In males, the minimum horizontal diameter was 7.5 mm at L1 in the 10–19.9 y age group (Table 2), while the maximum horizontal diameter was 14.2 mm at L5 in the 40–49.9 y age group (Table 6).

Vertical diameters. In females, there was a cephalocaudal increase of the vertical diameters from L2 through to L5 in all age groups except the 20–29.9 y age group. The mean vertical diameter of the L1 pedicle was greater than the mean vertical diameter of the L2 pedicle, in 4 of the 5 age groups (namely, 10–19.9; 30–39.9; 40–49.9 and 50+ y). In the 20–29.9 y age group the mean horizontal diameter of the L1 pedicle was similar to the diameter of the L2 pedicle (Tables 2, 3). The differences were statistically significant ($P < 0.001$).

In males, the lower lumbar pedicles (L4 and L5) had greater vertical diameters as expected. The diameter of the L5 pedicle exceeded the diameter of the L4 pedicle in all age groups (Tables 5, 6). The mean vertical diameter of the pedicle of the 3rd lumbar vertebra was the smallest among the 5 lumbar segments in all age groups except the 3rd and 5th decades, while the L1 pedicle had a greater mean vertical diameter than the L2 pedicle ($P < 0.01$) in the 10–19.9, 20–29.9 and the 40–49.9 y age groups. In the remaining 2 age groups (30–39.9 and 50+ y), the vertical diameter of the pedicle of L1 exceeded that of L3 only.

The mean vertical diameters of the lumbar pedicles of females ranged from 14.2 mm at L2 level in the 10–19.9 y age group (Table 3) to 18.2 mm at L5 level in the 30–39.9 y age group (Table 6). The corresponding minimum and maximum diameters for males were 14.8 mm at L3 in the 10–19.9 y group (Table 4) and 20.7 mm at L5 in the 40–49.9 y group (Table 6), respectively.

Age-related differences

There were differences, between the age groups, in the horizontal and vertical diameters of the pedicles at all the 5 lumbar levels. The pattern of variations differed in males and females.

Horizontal diameters. In females, the horizontal diameter was greater in the 10–19.9 y age group than in the 20–29.9 y group at all segmental levels. The smallest horizontal diameters were noted in the 20–24.9 y group. At the upper 3 lumbar levels maximum horizontal diameters in females were seen in the 10–19.9 y group. Variations in the horizontal diameters at the 4th and 5th lumbar levels with age were more subtle, suggesting that at these levels adult dimensions were probably attained very early, possibly by late adolescence. From the 20–29.9 y age group upwards, horizontal diameters of the pedicle showed moderate but steady increases at all lumbar levels, until the 6th decade. Differences between the mean horizontal diameters of the 10–19.9 y group and the 20–29.9 y group were highly significant ($P < 0.001$) at L1, L2 and L3 levels and marginal at L4 and L5 levels. The horizontal diameters of the pedicles of the 10–19.9 y group differed significantly ($P < 0.001$) from the diameters of all the other age groups at the various segmental levels. The t tests also showed that, at the upper 3 lumbar levels, the horizontal diameters of the pedicles of the 30–39.9 y group were significantly different ($P < 0.001$) from the diameters of the 10–19.9, 20–29.9 and 50+ y age groups.

In males, the mean horizontal diameters increased steadily from age group 10–19.9 y until age group 40–49.9 y at all lumbar levels except the 4th. A detailed study of the adolescent group showed that differences between the diameters of the 10–14.9 y group and 15–19.9 y group were highly significant ($P < 0.001$). The diameters in these age groups (especially the 15–19.9 y group) reflected the effect of the adolescent growth spurt. The results of t tests showed that the mean horizontal diameters of the 10–14.9 and 15–19.9 y groups differed significantly ($P < 0.001$) from the diameters of all the other age groups. The mean horizontal diameters attained in the 40–49.9 y group were higher than the mean diameters of all the other age groups at all levels. Variations of the pedicle diameters at the 4th lumbar level did not appear to follow a clearly defined pattern. A decline of horizontal diameters was noted in the 50+ y age group at all levels. The decline was highly significant at the upper 2 and the 5th lumbar levels ($P < 0.001$). The mean diameters of the 50+ y age group were, nevertheless, significantly greater ($P < 0.01$) than those of the 10–19.9 y group. It is noteworthy that, unlike the females of the same age, the 50+ y male subjects had smaller pedicle diameters than the 40–49.9 y group, especially at the upper 2 and the 5th lumbar levels. In both males and females, the differences between the horizontal diameters of the 40–49.9 and 50+ y groups were highly significant ($P < 0.001$).

Vertical diameters. In females, the differences between the mean vertical diameters of the pedicles of the 10–19.9 y group and the other age groups were highly significant at all lumbar levels. Vertical diameters showed a decrease from age group 30–39.9 y to age group 40–49.9 y except at the 1st lumbar level. From age group 40–49.9 y to age group 50+ y, significant increases ($P < 0.001$) in vertical diameters were noted.

In males, there was a marked increase of the vertical diameter from age group 10–19.9 y to age group 20–29.9 y ($P < 0.0001$) at all 5 lumbar levels. A decline of diameters was then observed from age group 20–29.9 y until age group 30–39.9 y ($P < 0.001$). At each lumbar level, differences between the vertical diameters of the pedicles of the 30–39.9 y group on one hand and the vertical diameters of the other age groups (i.e. 10–19.9, 20–29.9 and 40–49.9 y) were very significant ($P < 0.001$). With the exception of the 1st lumbar level, the vertical diameters of male pedicles increased sharply from age group 30–39.9 y to age group 40–49.9 y ($P < 0.001$). This was followed by an equally marked decline of diameters in the 50+ y group. The mean vertical diameter of the pedicle of the 40–49.9 y group was markedly greater ($P < 0.001$) than the mean vertical diameters of the pedicles of all other age groups.

DISCUSSION

The horizontal diameters of the pedicles of the adult subjects in the present sample correlate well with figures published by Krag et al. (1986) and Zindrick et al. (1987). With respect to sexual dimorphism in the diameters of the pedicles, the findings of the present study extend the report of Scoles et al. (1988) by showing that there are significant differences between the diameters of the pedicles of males and females. Additionally, evidence obtained from the study suggests that there are significant age-related differences in the diameters of the lumbar pedicles. The pedicles do not show a simple linear increase in diameters from the younger age groups to the older ones. Age-related changes could result in an increase of diameters in some age groups or a decrease at other ages. This trend appears to be in agreement with the pattern of age-related changes reported for other parts of the vertebrae. Studies reported by Allbrook (1956, vertebral bodies), Ericksen (1976, 1978*a*, *b*, vertebral bodies), Prêteux et al. (1985, vertebral cancellous bone), Oda et al. (1988, intervertebral discs), Amonoo-Kuofi (1991, intervertebral discs) clarified the fact that structural changes in the various components of the vertebral column during ageing are characterised by alternating phases of increase and decrease in the respective dimensions. Within the vertebral body, ageing was associated with remodelling, thickening and a 6-fold increase in the number of the weight-bearing trabeculae (Prêteux et al. 1985). In the intervertebral discs, histological evidence showed that there were cycles of regeneration and remodelling, presumably in response to prevailing mechanical demands on the vertebral column (Oda et al. 1988). Clearly, weight-bearing and mechanical factors appear to play important roles in morphological and functional adaptation of the vertebral column to the changing demands associated with growth. Corroborative evidence brought by Porter et al. (1989) established that in individuals aged 18 y and over, increasing levels of physical activity were associated with increasing strength of the vertebral column. The posterior elements of the vertebral bodies, in particular, have a marked ability to undergo regrowth and remodelling (Krenz & Troup, 1973; Fidler, 1988; Postacchini & Cinotti, 1992). It would seem, therefore, that if the pedicles were subjected to changing mechanical stresses, they would probably show appropriate variations in strength (or diameters). Studies reported by Pal & Routal (1987) suggested that, in the lumbar region, the pedicles play an important part in the transfer of weight from the neural arch to the anterior part of the vertebral column. The variations in the diameters of the pedicles associated with the different age groups could therefore be attributed to this weight-bearing function. Judging from its larger dimension and its wider variations with age, it seems reasonable to suggest that the vertical diameter probably contributes more to weight-bearing functions than the horizontal diameter.

The larger vertical diameter of the pedicle of the 1st lumbar vertebra (in both males and females) as compared with the vertical diameters of the 2nd and 3rd lumbar pedicles could also be explained by the weight-bearing function. The 1st lumbar pedicle is located at the thoracolumbar transitional junction. A report by Davis (1955) demonstrated that this junction was the site of a complex zygapophyseal joint (the thoracolumbar mortice joint) which was adapted to withstand marked compressive forces transmitted from the relatively immobile thoracic segment to the highly mobile lumbar segment of the vertebral column. He showed that the vertebrae and pedicles at this junction were reinforced to withstand the forces that had to be transmitted across this junction.

It was intriguing that, for any given vertebral level, the vertical and horizontal diameters did not show identical patterns of variation from one age group to another. Owing to the lack of corroborative morphometric information on the growth of the pedicles, it is difficult to determine the extent to which these differences in the variation of the diameters reflected normal growth pattern. The present sample was a cross-sectional one, and therefore the possibility that observed morphometric variations could be due, in part, to a secular trend in changing body size could not be excluded. Nevertheless, the fact that variations of vertical and horizontal diameters of any given vertebra were neither synchronous nor in the same direction suggests that, perhaps, the observed changes did not result from adverse environmental or nutritional factors.

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